



INFLUENCE OF HAZE LAYERS UPON REMOTELY-SENSED  
SURFACE PROPERTIES

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During the summer of 1971 the Laboratory for Applications of Remote Sensing (LARS) participated in an experiment to detect disease in corn caused by southern corn leaf blight. An aircraft was used to measure in several spectral intervals between 0.46 and 2.60 micrometers the solar radiation reflected by the earth's surface. The analysis of data gathered during the 1971 Corn Blight Watch Experiment revealed a number of unexpected features. One of particular interest was the appearance of bright and dark sides along the flightline of the aircraft. An example is shown in Figure 1, taken at 10:28 a.m. EST on June 30, 1971, over southern Indiana.



Figure 1. Data in 0.46-0.49 micrometer channel taken from June 30, 1971, flight over Pike County, Indiana (Segment 225).

The plane was headed south (top of figure) with surface illumination from the east (left) and ahead of the plane. Relative darkness on the left and brightness on the right is evident in the data as it appeared when displayed in digitized grey levels.

A check of the pilot's log revealed that visibility was estimated to be only 6 miles while hazy conditions were noted below the aircraft. The possibility that the presence of hazy layers may have contributed to the anomalous effects in the data prompted the computation of scattering angles for this flight. These are shown in Figure 2.

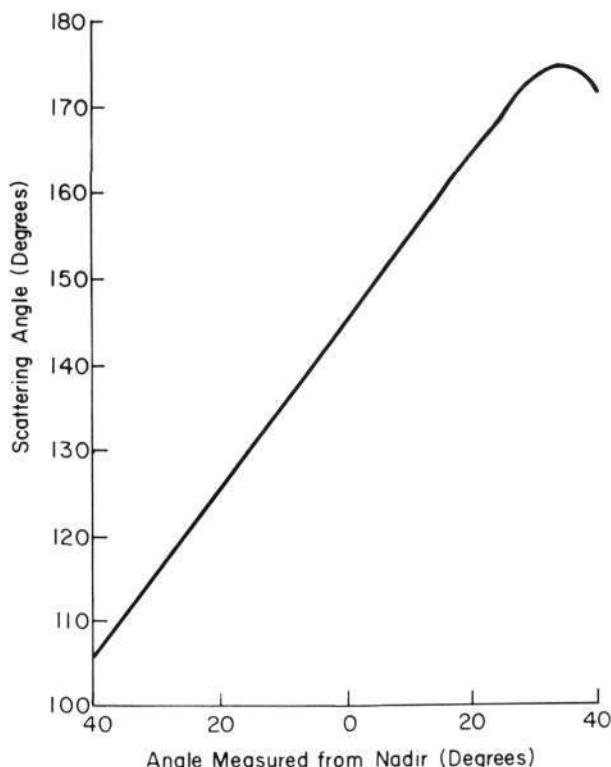


Figure 2. Scattering angles computed for June 30, 1971, flight over Segment 225.

The scattering angle varies from near side-scattering on the left (east) side of the flightline to near back-scattering on the right (west) side. Since the scattering properties of the aerosols which compose haze layers generally undergo marked variations over this range of scattering angles (Deirmendjian, 1969), an attempt to compute the expected variation of reflected intensities across the flightline was made. It

was first necessary to assign physical parameters to the haze. As a first case, the size distribution of Deirmendjian's haze L (Deirmendjian, 1969) was selected as being typical of a continental-type aerosol distribution. His tabulations of the elements of the scattering matrix for a water haze L allowed the computation of the scattering phase function for the scattering angle interval of interest. This function, shown in Figure 3, for a wavelength of 0.45 micrometers undergoes a minimum near  $120^\circ$  from which it rises to a relative maximum at  $165^\circ$  with a secondary minimum between this point and the maximum value for  $180^\circ$  backscatter.

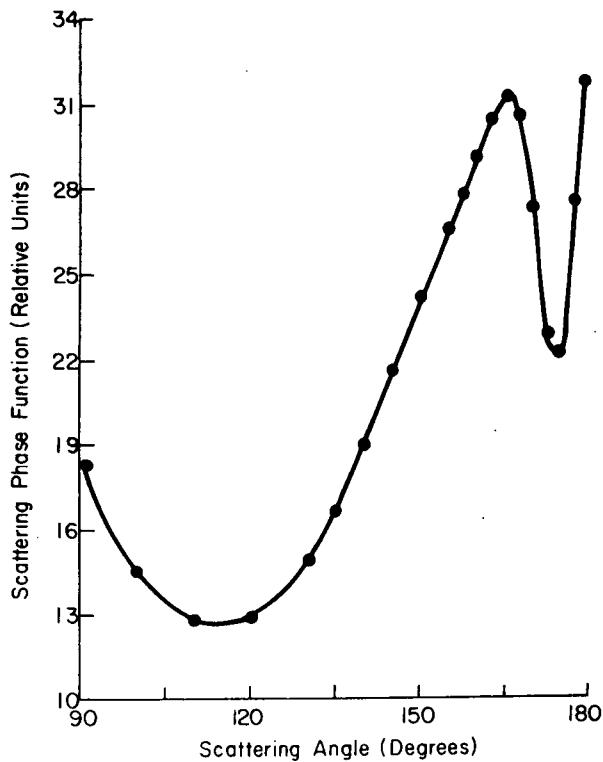


Figure 3. Scattering phase function at 0.45 micrometers as a function of scattering angle for a continental haze layer (after Deirmendjian, 1969).

Combination of the computed scattering angles of Figure 2 with the phase function in Figure 3 allowed an estimate to be made of the variation in reflected intensity across the flightline. The result for a wavelength of 0.45 micrometers is presented in Figure 4 as the predicted curve. Lowest values occur along the left (east) side of the flightline. These correspond to minimum values of the scattering phase function near  $120^\circ$ . As scattering angles increase moving to the right (west), intensity increases reaching a peak for  $165^\circ$  scattering angle. Beyond this point the reflected intensity decreases toward the right-hand side of the flightline.

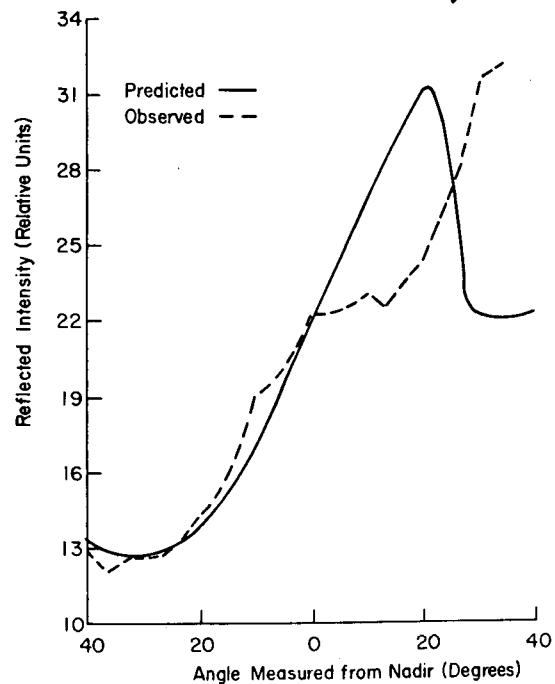


Figure 4. Comparison between predicted reflected intensity at 0.45 micrometers and observed values for 0.46-0.49 micrometers averaged for the length of the June 30, 1971, flight over Segment 225.

In order to obtain a measure of the agreement between these calculations and the observed intensities, the latter were averaged column-by-column for the total length of the flightline. The resultant values, computed for the 0.46-0.49 spectral interval, are shown as the observed curve in Figure 4. The agreement between the two curves is excellent for the left-hand side of the flightline, but differences as large as 30 percent occur near the right-hand side. At the present time, no satisfactory explanation exists for this discrepancy.

Although the agreement for this case between theory and observations is far from perfect, the results are sufficiently encouraging to warrant further study. At the present time, a model of atmospheric attenuation (Elterman, 1970) is being adapted for application to problems of this nature. The Elterman model consists of tabulations of attenuation coefficients at various wavelengths from 0.27 to 4.00 micrometers for several altitudes from the surface to 50 kilometers. The attenuation coefficients account for Rayleigh scattering, ozone, and aerosol extinction in the atmosphere. The manner in which the presence of a haze layer might be included in such a standard model is shown in Figure 5. In addition to reducing the radiation which reaches the surface and is reflected to the aircraft, the haze layer contributes a component through multiple internal scattering. As a result of the combination of these two factors, the spectral nature of the radiation received at the aircraft can be modified. It is hoped that it will eventually be possible to represent the haze layer by parameters such as an

effective transmissivity and reflectivity. In this way it will be possible to improve the identification of surface properties from multi-spectral remote sensed data.

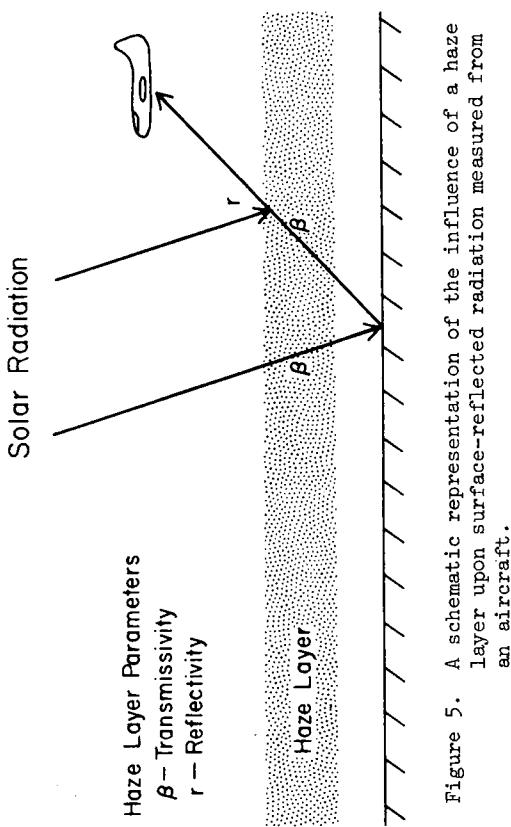


Figure 5. A schematic representation of the influence of a haze layer upon surface-reflected radiation measured from an aircraft.

#### ACKNOWLEDGMENTS

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#### REFERENCES

- Deirmendjian, D., 1969: Electromagnetic scattering on spherical polydispersions. New York, American Elsevier Publishing Co., 290 pp.
- Elterman, L., 1970: Vertical-attenuation model with eight surface meteorological ranges 2 to 13 kilometers. Air Force Cambridge Research Laboratories, Environment Research Papers No. 318, Bedford, Mass., 56 pp.